

ESTABLISHING A RELATIONSHIP BETWEEN MAXIMUM TORQUE PRODUCTION OF ISOLATED JOINTS TO SIMULATE EVA RATCHET PUSH-PULL MANEUVER: A CASE STUDY

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INTRODUCTION

As manned exploration of space continues, analytical evaluation of human strength characteristics is critical. These extraterrestrial environments will spawn issues of human performance which will impact the designs of tools, work spaces, and space vehicles.

Computer modeling is an effective method of correlating human biomechanical and anthropometric data with models of space structures and human work spaces (Figure 1). The aim of this study is to provide biomechanical data from isolated joints to be utilized in a computer modeling system for calculating torque resulting from any upper extremity motions: in this study, the ratchet wrench push-pull operation (a typical extravehicular activity task).

Established here are mathematical relationships used to calculate maximum torque production of isolated upper extremity joints. These relationships are a function of joint angle and joint velocity.

METHOD

Maximum torque data were obtained on a single subject during isolated joint movements of the shoulder, elbow, and wrist at angular velocities of 30 to 240 deg/sec at 30 deg/sec increments on the Loredan Inc. LIDO system. Data collection software tracked and stored joint angle data, as well as torque and velocity data, simultaneously. The angle versus torque

data was reduced using a least squares regression algorithm to generate polynomial equations relating the two variables, torque and joint angle at various velocities.

These torque functions were then tabularized for utilization by the computer modeling system (Figure 2). The modeling system then correlated the functions with the appropriate joints in an anthropometrically correct human model. A ratchet wrench task was simulated and the force vectors generated from these isolated joint equations were then summed to yield end-effector torque.

As a preliminary step in the model validation process, isotonic (constant load) maximum torque data were collected for the ratchet wrench push-pull operation. Plans to collect more controlled (restricted motions) isokinetic (constant velocity) ratchet wrench data to match model outputs are in progress.

RESULTS

Second order regression equations relating joint angle to end-effector torque of the shoulder, elbow and wrist in all axes, and directions at various velocities were established. The data indicated a relationship between the allowed velocity (i.e., decreased velocity was proportional to increased resistance) and the torque generated. As indicated in Figure 3, the maximum torque generated decreases as the velocity increases.

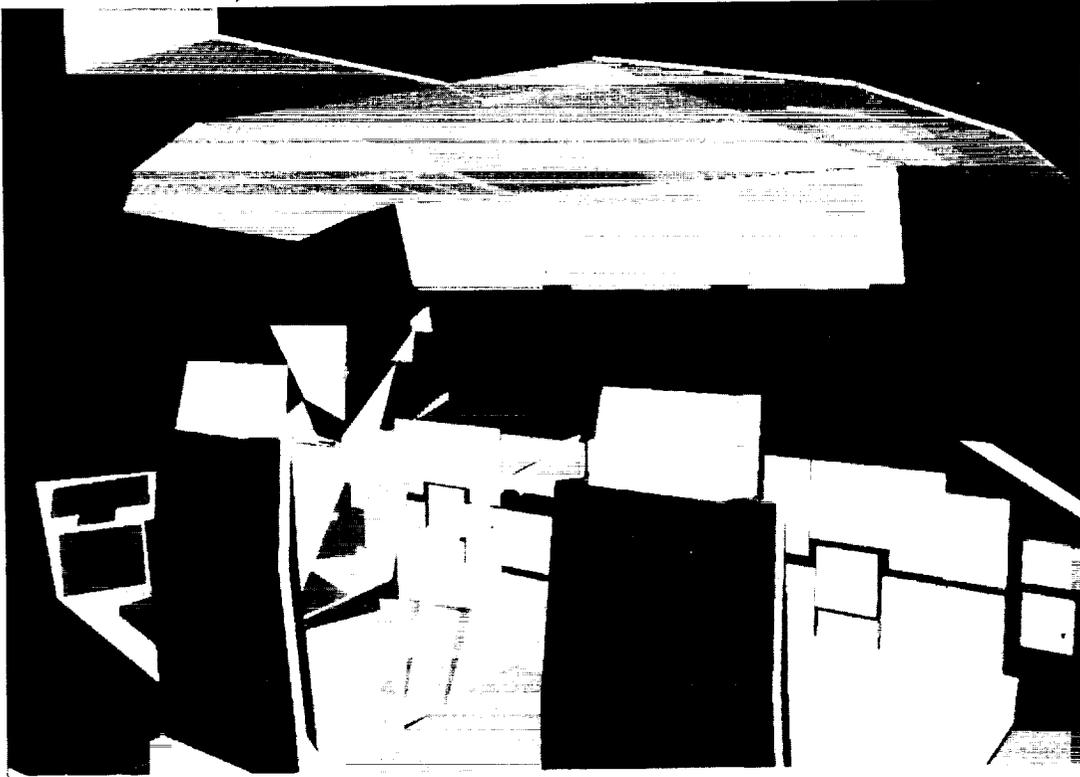


Figure 1. Man model representation in a work space.

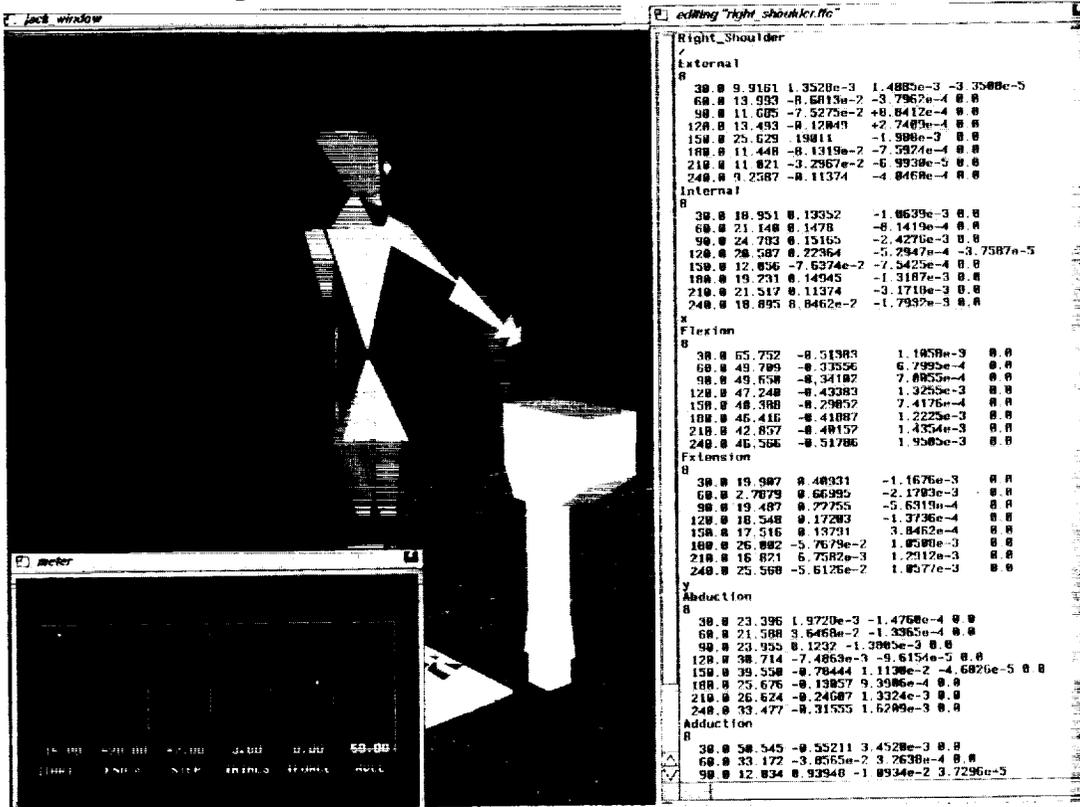


Figure 2. Torque function regression coefficients incorporated into man model.

Shoulder Extension
Velocities 30-240 deg/sec

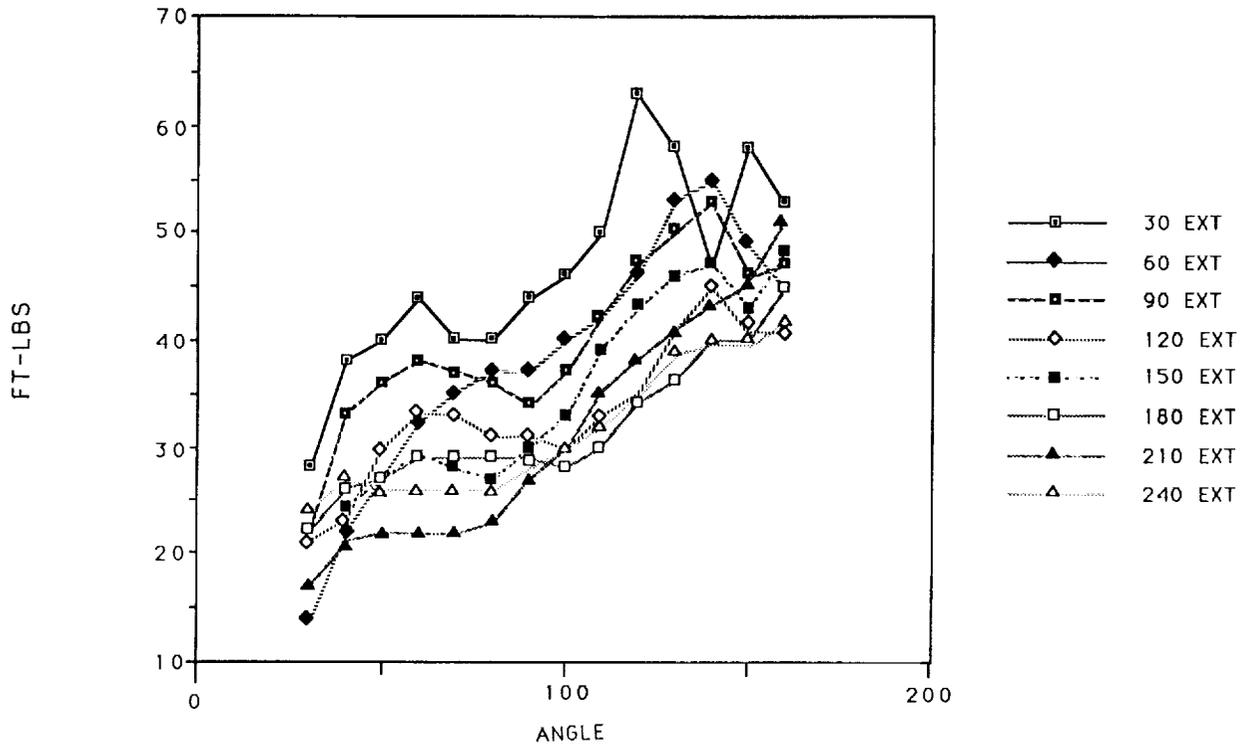


Figure 3. Shoulder regression equation at all measured velocities.

All the isolated joint relationships were coded into a flexible and interactive computer graphics model. This model allowed alteration of the initial position and joint angles of the human figure relative to the ratchet wrench. This flexibility allowed one to gauge the effects of body orientation on torque generated.

The calculation for torque generated was for the isokinetic ratchet wrench motion. Model validation data for this configuration is now being collected.

CONCLUSION

It has been demonstrated that a computer model may be a viable method to calculate

torque resulting from arbitrarily complex motions. Using regression equations derived from empirically measured torques for isolated joints, end-effector torque was calculated and displayed for an isokinetic ratchet wrench procedure (Figure 4).

For initial validation efforts, isotonic data on the ratchet wrench were collected. Because of the uncontrolled ratchet velocities in the isotonic measurements, model calculations (based on isokinetic configuration) were not acceptably accurate (up to 40% lower). An accurate validation and refinement of the model is contingent upon collection of very controlled (restricted motion) isokinetic data (constant velocity) of the ratchet wrench motion for more subjects.

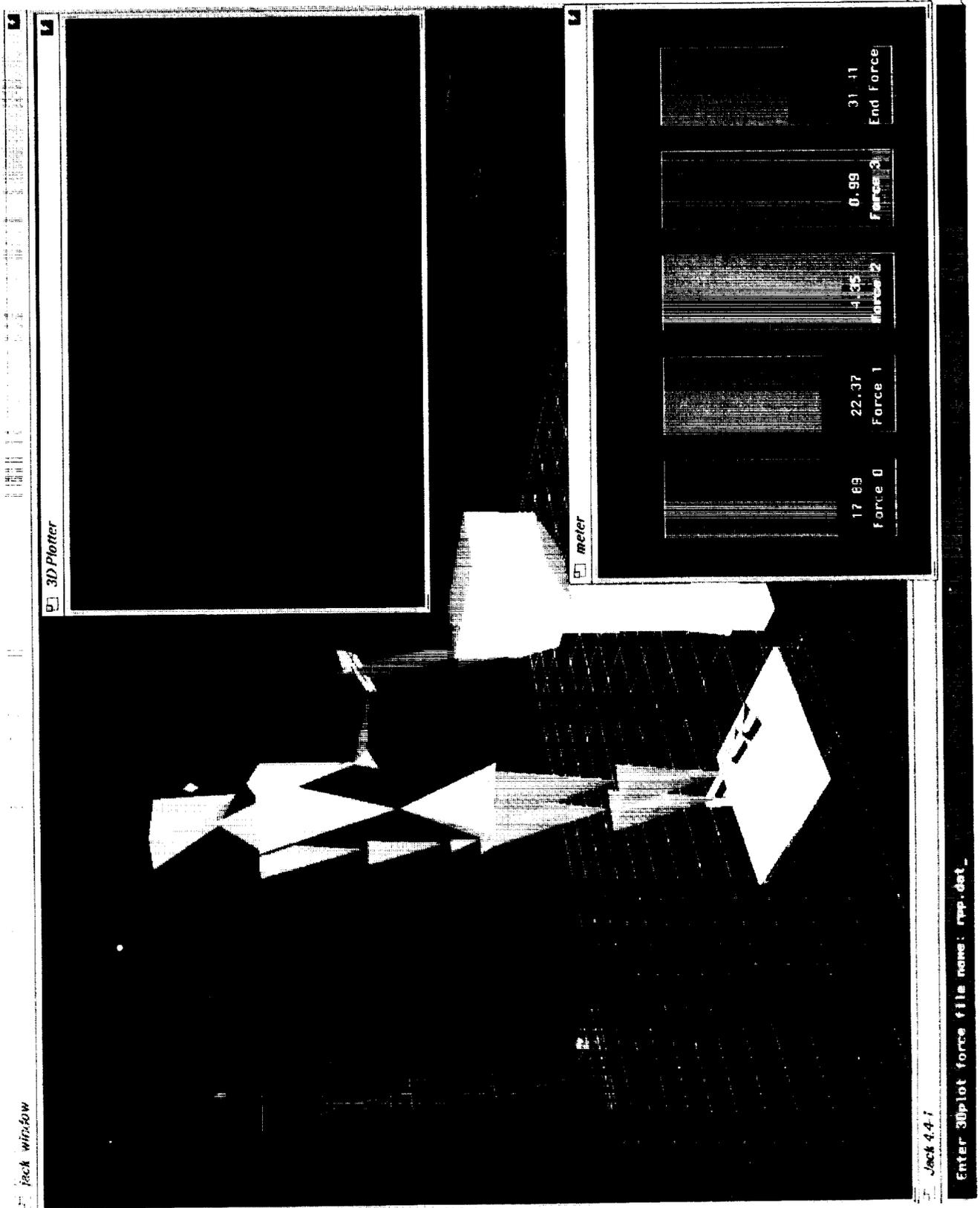


Figure 4. Display of joint and end-effector torques for the ratchet wrench task push-pull task.